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Geology of a Part of the Panamint Range, California

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GEOLOGY OF A PART OF THE PANAMINT RANGE, CALIFORNIA[1]

By F. M. Murphy

OUTLINE OF REPORT

ABSTRACT

The Panamint Range is a tilted fault-block, uplifted probably in Tertiary time and rejuvenated by very complex recent faulting on the west. This great block is approximately 100 miles long, but the reconnaissance geologic map covers only a tract in the southern portion of the range about 21 miles from north to south. The oldest formation consists of a great thickness of undifferentiated and

[1] Condensation of a part of a thesis submitted to the Balch Graduate School of the Geological Sciences of the California Institute of Technology. Abstract presented before the Cordilleran Section, Geological Society of America, April 13, 1929. (Geol. Soc. Am. Bull., vol. 41, p. 152, 1930.)

regionally metamorphosed rocks, embracing schists, gneisses, and marble, predominantly of sedimentary origin, injected by granitic rocks and cut by diabase dikes. These are overlain by less highly metamorphosed slaty schists and dolomitic limestones, separated by a nonconformity from a succession of rocks consisting largely of limestones, dolomites, and schists. The age of the rock formations is unknown, but is believed to range from pre-Cambrian to Lower Paleozoic. Structure within the range is not entirely clear and that of certain rock masses is indeterminable. The older rocks on the west slope show a westward dip of the foliation, while the younger formations, forming the crest of the range and the Death Valley side, dip gently eastward.

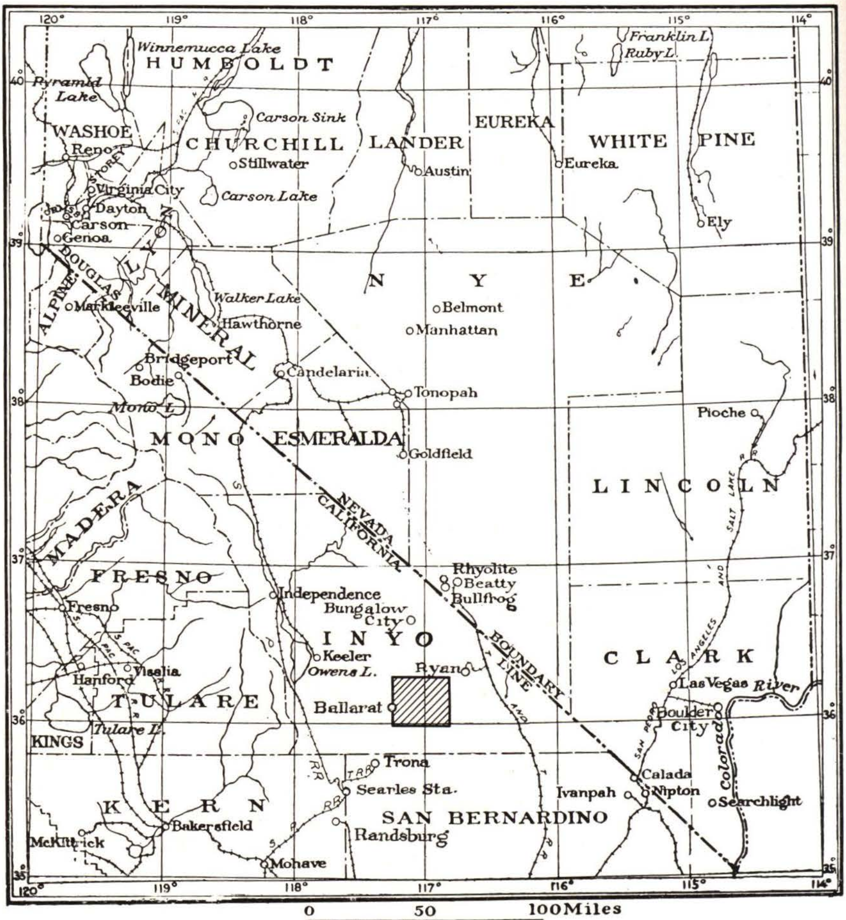

FIG. 1. Index map showing location of area (shaded) covered in this report.

INTRODUCTION

Object of the Report.

A twofold project of research in the Panamint Range was undertaken by the writer in 1926 upon the suggestion of Mr. L. F. Noble. In subsequent field seasons, a detailed study of the Panamint silver district and a general investigation of the geology of the region, were carried out. The report on the economic geology of the mining district has already been completed. In the regional study, petrology and stratigraphy were the most carefully investigated fields of geology, while the intricacies of faulting marginal to the range, were studied only in a general way. This faulting, however, is expected to be the subject of further investigations in the general region. The Panamint Range is one of the most prominent topographic features of the arid region of southeastern California and is one of the characteristic, though little known, Basin Ranges of this district. In this connection, its form, composition, and structure has especial significance. It is the hope of the writer that this contribution may be useful in extending geologic knowledge of this interesting desert range.

Location.

The area covered by the accompanying reconnaissance geologic map, embracing the tract of country that forms the particular subject of this investigation, is situated in Inyo County, southeastern California. Its general geographic position and routes of access are shown on the index map (Figure 1). The area is approximately 21 miles from north to south and 24 miles from east to west, and lies between parallels 36° 00′ and 36° 16′ and meridians 116° 53′ and 117° 15′. It contains about 500 square miles and includes a portion of the southern part of the Panamint Range.

The mountains are rather inaccessible especially the eastern side, bordering Death Valley. Apart from a few canyon roads on the west side of the range, the higher parts are reached only by a few rough trails. The almost deserted town of Ballarat, the only settlement in the area, is located at the foot of the range, in Panamint Valley.

The silver-bearing quartz veins of the Panamint district are of chief economic interest, although deposits of gold, lead, and antimony also occur in various places in this part of the range. The silver ores occur for the most part in limestone, but are also found in schist, in well-defined fissure veins, of probable Mesozoic age.

Previous Work.

The publications listed below[2] deal with the geology of this part of California. Only a few of them, however, specifically relate to that part of the Panamint Range discussed in this report. A paper on the geology of the Panamint mining district has recently been published elsewhere.[3]

[2] Fairbanks, H. W., Preliminary Report on the Mineral Deposits of Inyo, Mono, and Alpine Counties. Calif. State Mining Bureau, 12th Ann. Rept., pp. 472–478, 1894; * * * Notes on the Geology of Eastern California. Amer. Geol., vol. 17, pp. 63–74, 1896; * * * Mineral Deposits of Eastern California. Amer. Geol., vol. 17, pp. 144–158, 1896.

Spurr, J. E., Descriptive Geology of Nevada South of the Fortieth Parallel and Adjacent Portions of California. U. S. Geol. Survey Bull. 208, pp. 200–205, 1905.

Ball, S. H., A Geologic Reconnaissance of Southwestern Nevada and Eastern California. U. S. Geol. Survey Bull. 308, pp. 201–212, 1907.

Gale, H. S., Salines in the Owens, Searles, and Panamint Basins, Southeastern California. U. S. Geol. Survey Bull. 580, pp. 312–323, 1914.

Noble, L. F., The San Andreas Rift and Some Other Active Faults in the Desert Region of Southeastern California. Carnegie Inst. Wash. Yearbook, no. 25, pp. 425–428, 1925–1926.

Davis, W. M., The Rifts of Southern California. Amer. Jour. Sci., 5th Ser., vol. 13, pp. 57–72, 1927.

Wolff, John E., Route of the Manly Party of 1849–50 in Leaving Death Valley for the Coast. Pasadena, The Author, 1931.

[3] Murphy, F. Mac, Geology of the Panamint Silver District, California. Econ. Geol., vol. 25, pp. 305–325, 1930.

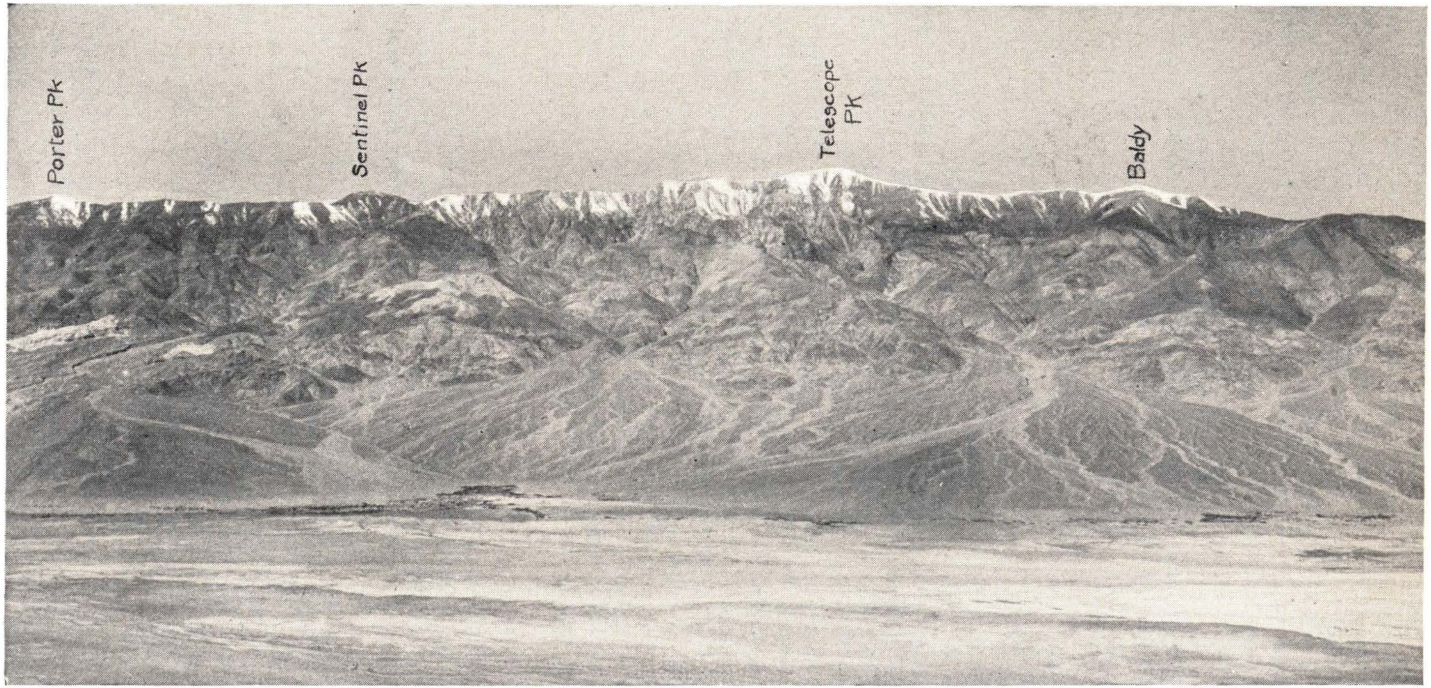

FIG. 2. General view of the eastern front of Panamint Range across Death Valley, from Dante's View in the Black Mountains. The difference in elevation is from approximately 250 feet below sea level to 11,045 feet above.

The Panamint Range was probably named by John Lilliard of the Darwin French party—a group of prospectors from San Francisco, who in May, 1860, set out in search of a mythical silver deposit, the 'Gunsight lead,' which was believed to have been discovered by the emigrant party that was lost in Death Valley in 1850.

Acknowledgments.

The writer desires to thank his many friends in the area for numerous courtesies extended, and to express his appreciation for their active interest shown during the progress of the work. He is especially grateful to Messrs. F. L. Ransome, J. P. Buwalda, Rene Engel, and J. E. Wolff for their kindness in accompanying him on short field trips to the region, for suggestions concerning many of the problems involved in the work, and for reviewing the manuscript.

Climate and Vegetation.

In consequence of the considerable difference in altitude there is a corresponding variation in both climate and flora between Panamint Valley and Death Valley on the one hand, and the Panamint Range on the other. The distinction ranges from those exemplified by the comparatively well-watered crest of the range, with its substantial timber growths, to the arid valleys with their scant growth of typical desert plants.

In the valleys the air is relatively dry throughout the year, the winters are moderately cold with occasional light flurries of snow, and the period from June until October is usually oppressively hot, both day and night. The mean summer temperature for Death Valley is about 96° Fahrenheit. In 1913 the United States Weather Bureau station at Furnace Creek (Greenland) Ranch, altitude 178 feet below sea level, recorded a shade temperature of 134° Fahrenheit. This is the highest officially reported natural shade temperature in the world. The mean winter temperature, as registered over a period of many years at the Furnace Creek Ranch, is about 60° Fahrenheit. Over a long period, the annual average precipitation for Death Valley is about 1.5 inches, but it is approximately twice that amount in Panamint Valley.

In the upper reaches of the Panamint Range, the winters are moderately cold; summer days are warm and the nights delightfully cool. It would be extremely difficult to estimate the precipitation in any considerable part of the Panamint Range, but it is of course very largely in excess of the precipitation in the adjacent valleys. The snow line rarely falls below an elevation of 6000 feet, although there are occasional exceptions. Cloudbursts and local excessively heavy rains occur both during the summer and winter.

The vegetation of the Panamint Range is typical of that of the higher desert ranges generally. Three distinct zones of plant growth can be made out. The lowest occupies the valleys on either side of the range and the desiccated slopes up to an altitude of about 6500 feet. The sparse vegetation of this zone includes Creosote Bush (*Larrea tridentata var. glutinosa*). The second zone is the lower half of the conifer belt and extends to an altitude of about 8500 feet. It is marked by the Desert Juniper (*Juniperus californica var. utahensis*) and the Pinon Pine (*Pinus cembroides var. monophylla*) while common shrubs occurring in this region are: Mexican Tea (*Ephedra viridis*), Cliff Rose (*Cowania mexicana var. stansburiana*), and Common Sagebrush (*Artemisia tridentata*). The third zone is the upper conifer belt and extends from 8500 feet to the highest peaks and ridges of the range. The important representatives include the Limber Pine (*Pinus flexilis*) and the Hickory Pine (*Pinus aristata*) with an occasional Sierra Juniper (*Juniperus occidentalis*). Other shrubs are: Desert sweet (*Chamaebariaria millifolium*), Small-leaf Mahogany (*Cercocarpus intricatus*) while Mountain Mahogany (*Cercocarpus ledifolius*) is conspicuous as a shrub or tree.

BROAD TOPOGRAPHIC AND PHYSIOGRAPHIC FEATURES

The Panamint Range occupies a commanding position, forming the west wall of Death Valley and the east wall of the somewhat smaller, but very similar, Panamint Valley. It is about 100 miles long and extends from latitude 35° 35′ N. to 37° 00′ N. The line of demarcation between the Last Chance Range on the north and the Panamint Range on the south is not sharply defined. On the south the range terminates at Leach trough. It has a dominant north-northwesterly trend but the part of the range with which this paper is concerned, substantially parallels the meridian and averages about 18 miles in width. The rather sharp crested ridge, which marks the axis of the range and averages approximately 9500 feet above sea level, gradually culminates with commanding eminence in Telescope Peak, altitude 11,045 feet. From the sea level contour line in Death Valley to the summit of Telescope Peak, the average grade is 1000 feet to a mile for a horizontal distance of 11 miles. This steep acclivity is perhaps only exceeded in the United States by that of San Jacinto Peak in southern California. Though the east slope of the Panamint Range is therefore abrupt and rugged, it is less precipitous than that of the west flank.

The range is scored by a considerable number of great canyons, spaced at fairly equal intervals and extending generally normal to the trend of the range. These are separated by long rather even-crested ridges. The canyons are notably steep and rugged, with walls in some places rising vertically for hundreds of feet. This is especially true of canyons on the west side of the range. Locally they are mere slits in bedrock, and a few of them contain falls. The grade of the canyons on both flanks of the range average generally from 15 to 18 per cent.

On the east side of the range the contact of bedrock and alluvium is sinuous while on the west side it is relatively rectilinear. The heads of the alluvial fans on the west side of Death Valley attain a height of about 2000 feet above the playa, which nestles below the steep west escarpment of the Black Mountains. These huge fans coalesce to form a belt averaging four miles in width along the east base of the Panamint Range. The piedmont belt is broadest in Death Valley opposite Dante's View (Figure 2) but diminishes in breadth farther to the north. On the east side of Death Valley playa, the alluvial fans flanking the Black Mountains are very small in comparison with those described above. They are, moreover, formed of fresh materials in contrast to the decomposed rock debris of the fans on the west side. In Panamint Valley, which resembles Death Valley, the playa hugs the small alluvial fans to the east, along the base of the Panamint Range, while to the west of the playa long alluvial slopes rise to the flanks of the Argus Range.

Although mudflows have occasionally contributed to the formation of alluvial fans, the field evidence observed in this arid region has led the writer to consider that they are of minor significance as agents of erosion. A mudflow of considerable magnitude occurred in Surprise Canyon late in the afternoon of July 26, 1917, occasioned by a cloudburst near the head of Woodpecker Canyon, a north branch of Surprise Canyon. According to the only living witness of the flood, the water was 40 feet deep in the 'Narrows' of the canyon and the road was lowered 12 feet below its original level for a distance of about one mile. Like many of the mudflows described by Blackwelder,[4] the Surprise Canyon flow is characterized by preponderance of boulders. Its recency is indicated by absence of streamlet channels on its surface. It could not be ascertained how far the large fresh boulders, incorporated within the mudflow, were carried at the time of this flood, but in view of their well-rounded condition, it seems permissible to assume that most of them were not transported directly from their sources at the time of the flood. Trees up to $2\frac{1}{2}$ feet in diameter, however, were moved many miles down the canyon and were partly or completely buried in the layer of mud and rocks which covered the former surface of the fan. The present lobate layer of bouldery mud is 2 feet thick at its margin and covers roughly 10 per cent of the present fan area. Cutting by streams in the canyon below the mudflow surface varies widely from place to place, reaching a probable maximum depth of 15 feet. How much of this figure may represent dissection immediately after the flow of mud and rocks, can not of course be estimated but it may have been considerable.

Remnants of an old erosion surface are preserved in this part of the Panamint Range, like those previously noted by Ball[5] in the area farther to the north. Ball further mentions the existence of similar old topographic forms on the Kawich, Amargosa, and Belted ranges. Ferguson[6] found a similar topography on the Toquima Range. Meinzer[7] reported similar topographic forms on the Toyabe Range and Buwalda[8] described the occurrence of an early old-age topography on Cedar Mountain. Although vestiges of subdued topography are everywhere present on the western slope of the Panamint Range, the belt varies considerably in width and in degree of topographic development. In the southern part of the range the largest remnant of this old land surface is represented by the peculiar depressions known as South Park and Middle Park, which lie at an elevation of nearly 6500 feet, and are drained westward through South Park and Middle Park

[4] Blackwelder, Eliot, Mudflow as a Geologic Agent in Semiarid Mountains. Geol. Soc. Am. Bull., vol. 39, pp. 465–484, 1928.

[5] Ball, S. H., A Geologic Reconnaissance in Southwestern Nevada and Eastern California. U. S. Geol. Survey Bull. 308, pp. 16–17, 119, 161, 202, 1907.

[6] Ferguson, H. G., Geology and Ore Deposits of the Manhattan District, Nevada. U. S. Geol. Survey Bull. 723, pp. 61–62, 1924.

[7] Meinzer, O. E., Ground water in Big Smoky Valley, Nevada. U. S. Geol. Survey Water-Supply Paper 375, p. 90, 1915.

[8] Buwalda, J. P., Tertiary Mammal Beds in West-Central Nevada. Univ. Calif. Publ., Bull. Dept. Geol. Sci., vol. 8, pp. 358–359, 1914.

Canyons. Similar topography characterizes a large area north of Wildrose Canyon, in which the drainage divide lies somewhat south of the center of the area. The country south of the divide is drained into Wildrose Canyon and Panamint Valley, whereas to the north the drainage is through Emigrant Canyon into Death Valley. Owing to the

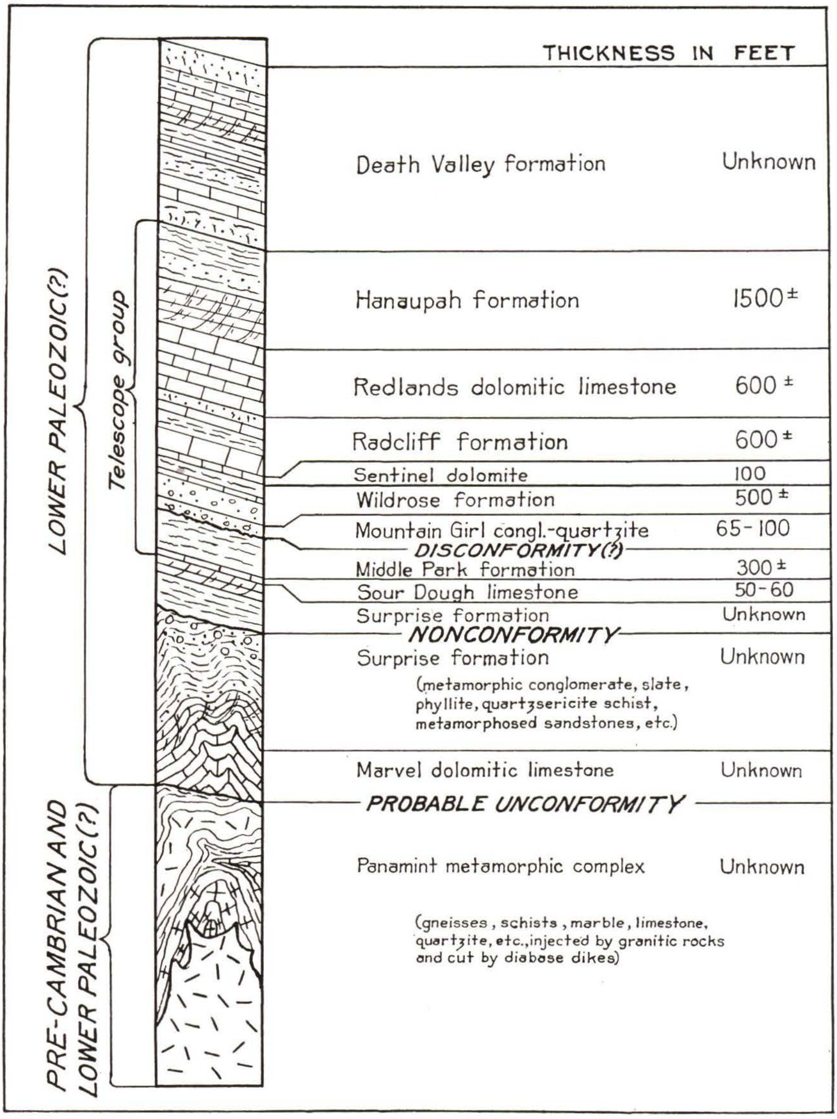

FIG. 3. Generalized columnar section of rock formations in the southern part of the Panamint Range.

absence of Tertiary volcanic rocks in the area studied, this old erosion surface can not be definitely assigned to any particular age, although it is undoubtedly a counterpart of others described in the Basin Ranges, many of which have been considered late Pliocene in age.

STRATIGRAPHY AND PETROLOGY

Summary of Stratigraphic Relations.

Although sedimentary, metamorphic, and igneous rocks are all represented in the area under consideration, the dominant types range from highly metamorphosed paragneisses and paraschists to less greatly altered argillites and limestones. The oldest formation consists of a considerable thickness of undifferentiated and regionally metamorphosed rocks embracing schists, gneisses, and marble of likely pre-Cambrian age. The overlying formations, which appear to be separated by an unconformity, are for the most part less strongly metamorphosed and consist chiefly of dolomitic limestones and slaty schists. Though the ancient crystalline rocks are intensely folded and no regular stratigraphic sequence was recognized, the unconformably overlying formations making up the crest of the range and the eastern slope, dip rather gently eastward. They consist largely of dolomitic limestone, schists, slates, argillites and intermediate facies. Owing to the short time devoted to the study of the Death Valley side of the range, the order of superposition of the various stratigraphic units was not completely determined. In consideration of their lithologic character, these rocks are believed to be of Lower Paleozoic age. It has not yet been possible to correlate any of the rock formations in this part of the Panamint Range with other sections in the general region, and for this reason new formation names are here applied. (Figure 3.)

Panamint Metamorphic Complex.

Distribution and General Features.

The name, Panamint metamorphic complex, is applied to a series of metamorphic crystalline rocks, presumably in large part of sedimentary origin, which occupies a large area in the southern part of the Panamint Range. The prevailing types include biotite-muscovite-quartz schist, quartz-muscovite gneiss, biotite-quartz gneiss, actinolite-biotite-quartz schist, marble, and limestone. The only metamorphic rocks of known igneous origin are sheared granite gneiss and hornblende schist. These rocks have been injected by granite and aplite and cut by diabase dikes.

Gneisses and Schists.

The predominating rocks of the complex are gneisses and schists in which there is much variety in coarseness of crystallization, cleavability, and megascopical appearance. The several intergrading facies vary widely in composition and texture from true gneisses and schists with well-marked foliation, to less highly metamorphosed impure quartzitic rocks, with foliation hardly perceptible. Inasmuch as the formation contains many gradations between coarse gneisses and finer grained banded schists, any description of one variety would not be entirely applicable to another. The following minerals have been identified in these rocks, and occur in various proportions: quartz, muscovite, biotite, microcline, plagioclase (generally albite), orthoclase, microcline-perthite, actinolite, hornblende, epidote, augite, zoisite or clinozoisite, magnetite, titanite, apatite, and zircon.

Briefly, these ancient rocks are so completely crystalline and have been so greatly metamorphosed, that little trace remains of their original components, whether of sedimentary or of igneous origin. In certain rock masses there is definite indication of former bedding. In others this is wholly lacking. The controlling factors are the type of the original rock, the extent of folding, and the degree of metamorphism. The marked change in composition from place to place as well as the lithologic variation across apparent "beds" which range from mere laminae to massive bands, suggests a sedimentary series. Certain lenses and layers are in places found to be parallel to the bedding at contact with other rocks of the series where the alternation of material shows which of these is the plane of stratification. Hence

FIG. 4. An exposure of closely sheeted marble in Surprise Canyon.

such lenses can be provisionally accepted as indications of stratification elsewhere. Furthermore, in places sheared quartzite pebbles, not completely destroyed by metamorphism, indicate the presence of original conglomeratic material.

Under the microscope the manifestation of extreme shearing is the most conspicuous feature of the rocks. This shearing is in a far more advanced stage in some parts of the same rock mass than in others. Severe cataclastic effects are everywhere evident which have resulted in the obliteration of original features. In most of the sections examined it was not possible to recognize the remains of detrital material, although rounded clastic grains of zircon and quartz were observed. Quartz preponderates over all other mineral constituents. This is particularly true of the assemblage quartz, muscovite, and biotite. Calcic minerals are generally absent. These features are strongly suggestive of the derivation of the rocks from quartzose sediments. Further, the association of these rocks with beds of limestone and marble, and their similarity to metamorphic rocks of known sedimentary origin, strengthens the view that the series as a whole originally consisted of sediments.

Limestone and Marble.

Many of the limestone bodies occur near the west base of the range. They are varicolored but often light-brown to buff on weathered surfaces and of varying degrees of crystallinity. Intercalated schist lenses are not uncommon. The limestones are generally contorted and irregularly banded, light and dark. They are always impure and cherty, and in most exposures finely speckled with sericite.

Extensive areas of dolomitic marble occur in several localities. The rock is massive, fine to medium-grained, white to grayish-white where fresh, and buff to light-brown, where weathered. The rock is frequently characterized by irregular lenticular dark streaks probably composed of carbonaceous matter. Sericite and bladed tremolite are common megascopic constituents. The latter is particularly noticeable along shearing planes. Figure 4 shows the close sheeting of marble in Surprise Canyon.

Sheared Granite Gneiss.

The largest body of an original igneous rock within the Panamint metamorphic complex is a sheared granite gneiss which forms an irregular strip of country near the west base of the range. There is a general uneven distribution of gneissic structure. The development of foliation is more marked in some parts of the rock mass than in others, but the rock is never massive. Metamorphism, however, has not proceeded far enough to obscure its original igneous texture.

The rock is white to gray in color, notably fresh, and in its most typical form is a coarsely banded gneiss, composed of feldspar, quartz, muscovite, and more rarely biotite. The most conspicuous feature of the rock in thin section under the microscope, is the manifestation of extreme shearing. The peripheral shattering and granulation of the large grains has given rise to typical mortar structure of the irregular, interlocking and dovetailing granules. The large feldspars are generally microcline, with whatever crystalline boundary they may have once possessed obliterated by the great mechanical changes they have undergone. Evidently unmixing during metamorphism has resulted in blebs and streaks on the feldspars which prove to be albite. In addition, shearing has produced a very pronounced pressure twinning of the original feldspar crystals as well as marked undulatory extinction. Other primary minerals are orthoclase, albite-oligoclase, and muscovite. Secondary minerals are muscovite, sericite, chlorite, and magnetite with frequent variations in the proportions of these.

World Beater Porphyry (porphyritic granite).

This rock forms a roughly quadrangular area of about 6 square miles, and stretches from Pleasant Canyon to Happy Canyon. The age relations of this mass to the other rocks of the complex are not entirely clear. It is not always easy to draw a definite contact between the porphyritic granite and the quartz-biotite gneiss with which it is in contact on the west. There is a possibility that the granite and the gneiss grade into each other, and if this be true, the intergradation is probably a result of absorption of the gneiss by the granite when injected. The granite is provisionally regarded as pre-Cambrian.

The porphyritic granite is a coarse-grained gray rock, brownish where weathered, containing fair-sized phenocrysts of potassium feldspar and smaller ones of plagioclase, and in addition biotite, muscovite, and abundant quartz. The rock is decidedly gneissic in places with very irregular streaks of biotite alternating with siliceous streaks containing little or no feldspar. This is especially true near the borders of the mass. Under the microscope the rock exhibits considerable

FIG. 5. Hornblende diabase dike cutting aplite, The Narrows, Surprise Canyon. The dike has a width of about six feet. The walls of the canyon rise vertically for several hundreds of feet at this point.

cataclastic effects. Moreover, these effects vary considerably in magnitude in the few sections examined. The most significant feature is the tremendous shattering of the grains and the subsequent development of biotite, quartz, albite, and muscovite. The feldspars have been given a microperthetic effect due to prominent streaks and blebs. These have probably resulted from unmixing during metamorphism, and their index of refraction would indicate albite. Albite also occurs as a filling around primary orthoclase and microcline.

Aplite.

As dikes and irregular masses, aplite invades the rocks of the complex and attains some local prominence. These aplites are probably pre-Cambrian in age and may or may not have been intruded prior to the regional metamorphism of the complex. The comparatively slight granulation in them and the lack of metamorphic minerals might indicate a later and feeble dynamic metamorphism.

The typical aplite, as exemplified by the large intrusive body in Surprise Canyon, is snow-white in color and notably massive with megascopic feldspar, quartz, and muscovite. The microscope reveals a medium-grained hypidiomorphic granular aggregate of oligoclase-albite, orthoclase, quartz, microcline, and muscovite, named in descending order of abundance. The rock is rich in quartz in both small and large grains, but the smaller grains are secondary and arranged in typical sutured texture. The large quartz grains show strong to moderate undulatory extinction. Dark minerals are wholly lacking aside from sporadic crystals of biotite. Apatite is an accessory mineral.

Diabase.

Diabase dikes and more rarely sills, occasionally occur, cutting the gneisses, schists, and granitic rocks of the Panamint metamorphic complex. In some places they occupy zones of fissuring or jointing, in others they are injected along the planes of schistosity and as such generally strike north and dip west from 45° to 70°. One of these dikes, cutting aplite, is shown in Figure 5. Striking contrast is shown between the unusual aplite, snow-white in color, and the dark-green diabase, filling a fissure or joint.

The diabase is an aphanitic, fine to medium-grained rock. Microscopically, it consists essentially of augite and labradorite, but in a few dikes green hornblende is an important constituent, paramorphic after a brown to yellow pleochroic variety approaching barkevikite. The minerals are panidiomorphic with medium-crystalline ophitic aggregates in which the usual place of augite is more rarely taken by hornblende. Crystals of olivine, largely altered to serpentine, are occasionally noted. Magnetite and biotite are accessory minerals.

Origin and Structural Features.

Although the sequence of intrusions is, for the most part, unsolved by this reconnaissance, it is apparent that the igneous rocks are not all of the same age. Though intrusive granitic rocks have played their part in local folding and recrystallization, yet the dominant process seems to have been more regional in character, occasioned by deep burial and mountain-making forces. A general uneven distribution of gneissic structure is recognized. Nevertheless, it appears that there has been a more or less uniform result produced by metamorphism in originally dissimilar rocks.

Structure within the complex is not entirely clear and that of certain rock masses is indeterminable. Secondary structures have made it impracticable to recognize any regular stratigraphic sequence, and the highly crumpled condition of many of these rocks, seriously hampers any attempt to unravel their probable complex structural history. The irregularity is perhaps partly original. Several schist and limestone bodies occur in great lenses, which thin to the north and south. The dominant trend of the foliation in any of the schist and gneiss areas of any considerable size, is northward and the dip, from

45° to 70° westward, but considerable deviation from this trend and attitude was seen in other parts of the area. In smaller masses, the strike and dip of the schistose cleavage is often quite variable. It would appear that more often the schistosity is approximately parallel with whatever larger banding, due to differences in composition of the rocks, may be discernable. This would be accepted as an indication that the schistosity is roughly parallel with the original bedding planes of the rocks. However, more detailed work would be necessary to substantiate this view.

The age of this assemblage of rocks is unknown. It is suggested, however, that a highly brecciated and crumpled limestone occupying

FIG. 6. Looking north from a point in Hall Canyon about five miles from its mouth, showing lenticular and interbedded character of rocks of the Panamint metamorphic complex. The light rock is marble and the dark, mica and actinolite schists.

a large lenticular body near the west base of the range, locally bears close lithologic similarity with the Eldorado limestone (formerly called "Prospect Mountain limestone") of Cambrian age.[9] It is very improbable that any of the rocks are younger than Cambrian. In view of the fact that they are largely coarse-textured gneisses and schists, it seems logical to regard them as pre-Cambrian. The fact that the rocks are regionally metamorphosed and in places intensely folded, would tend to strengthen such a conclusion.

[9] Hague, Arnold, Abstract of Report on the Geology of the Eureka District. U. S. Geol. Survey Third Ann. Rept., pp. 253, 254, 1883.
Walcott, C. D., Cambrian Geology and Paleontology. No. 5: Cambrian Sections of the Cordilleran Area. Smithsonian Miscell. Coll. No. 1812, Washington, p. 184, 1908.

Probable Unconformity.

It is here suggested that an unconformity separates the rocks of the Panamint metamorphic complex from the Marvel dolomitic limestone and the Surprise formation, although no direct evidence to support this supposition was obtained. It is difficult to separate the rocks into distinct groups. Their relations have not been closely studied and await interpretation. There exists, however, a striking contrast between the highly metamorphosed coarse-textured gneisses and schists with well-developed foliation, and are locally intensely folded, and the apparently younger formations composed essentially of fine-textured slaty rocks that are probably less highly folded. When two series of rocks occur together, one of which is more crystalline, more intensely folded and more highly metamorphosed than the other, it is a legitimate supposition that the former is older than the latter and is separated by a change in dynamic conditions. This assumes that the two series of rocks are of comparable susceptibility to metamorphism.

Marvel Dolomitic Limestone.

The Marvel dolomitic limestone, named from a branch of Surprise Canyon in which region it covers a prominent area, is essentially a light bluish-gray cherty rock of varying degrees of crystallinity. Tremolite and muscovite are abundant, an unusual feature in a limestone not very highly crystalline. The bedding is greatly contorted in some places and the rock decidedly schistose. Furthermore, it shows irregular mottling, due to brecciation. Suggestions of fine lines of stratification can occasionally be noted in fragments making up the mottled breccia. A partial chemical analysis of crystalline unaltered material gave the following results: CaO — 31%, MgO — 20%.

The contact of the Marvel dolomitic limestone with the overlying Surprise formation is nowhere sharply defined and at no place can be called a normal depositional contact. There is usually a gradation from a true limestone to a true schist for a distance of from 5 to 30 feet. The limestone simulates an intrusive relation to the schist, which suggests a squeezing into the less competent layers of the overlying Surprise formation.

Twelve separate areas have been distinguished in the reconnaissance mapping of this formation. The irregular shape of these limestone areas is probably due to a combination of several causes. The fact that in some places the formation contains interspersed irregular but generally lenticular beds of schist, indicates that the deposition of the limestone was an interrupted process. The several areas represent infolded portions of the Marvel dolomitic limestone which were probably deposited either as a single lens or as a series of lenses. Then followed intense compression and complex folding to such a degree that bedding was almost wholly obliterated, and consequently the structure can not be determined. With the subsequent planing-off by erosion of all the upper parts of the folds and their truncation down to the level of the present surface, it is possible to visualize the shape and distribution of these irregular areas. In many respects, therefore, these limestones are analogous to those of the Calaveras formation of the Sierra Nevada, California, and the Zanzibar limestone of the Manhattan district, Nevada. In a few places where bedding has been recognized, dips up to 45° were measured.

All traces of organic structure have been destroyed. Near the south base of Sentinel Peak, the limestone is made up of oölite-like nodules, which closely resemble those of an Ordovician limestone from the Inyo Range, California.[10] In the absence of diagnostic fossils, the age of the rock is unknown. Tentative assignment to the Lower Paleozoic has been made largely on lithologic grounds, particularly the mottled appearance, high magnesium content, and the intensely folded and often schistose condition of the rocks.

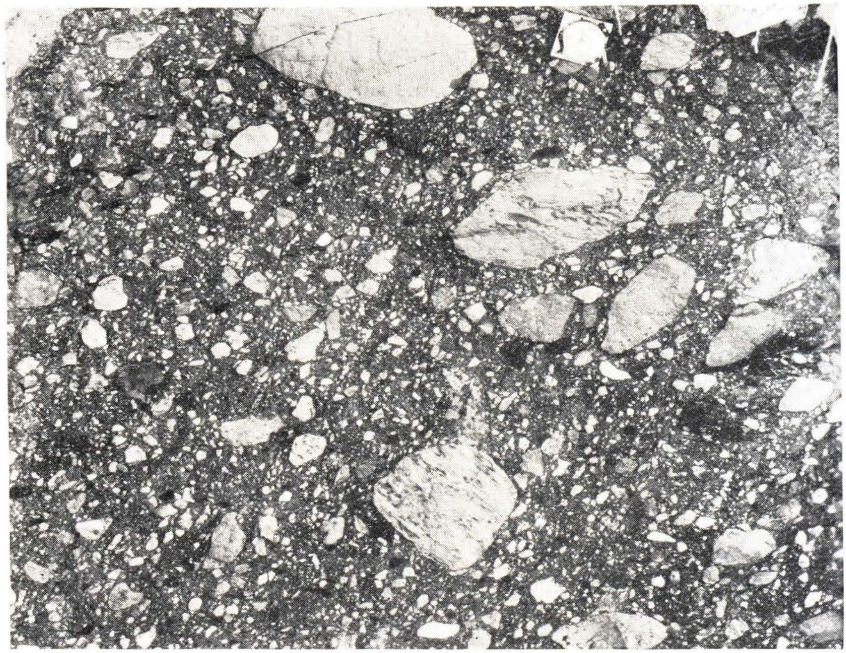

FIG. 7. View showing details of conglomerate schist within the Surprise formation, Panamint mining district. Most of the fragments are limestone but there are some of quartzite. Many of the limestone boulders are themselves conglomeratic and most of them have been sheared.

Surprise Formation.

Distribution and General Features.

The name, Surprise formation, is given to a series of predominantly fine-textured flaggy or slaty rocks which occupy an irregular strip of country on the western side of the range. The most significant feature is perhaps the large number of rock types represented, and there is in consequence a marked change in composition from place to place. Owing to their fine-grained, compact character, few minerals can be identified by the unaided eye. Though undeterminable megascopically, these rocks show rather complex characteristics readily apparent in thin sections under the microscope, and the classification

[10] Material collected by Dr. W. P. Woodring.

of the various facies rests entirely with the microscope. Although most of the rocks are schistose to a greater or lesser degree, this feature is not always marked in the hand specimen and many of them are rather massive. The prevailing rock types are: conglomerate schist, actinolite schist, ottrelite schist, quartz-sericite schist, slate and phyllite, quartz-biotite-tourmaline schist, metamorphosed sandstones and grits, and a relatively few interstratified irregular beds of brown limestone. There exist, however, all gradations and combinations of the above very generalized varieties of rocks making up the Surprise formation. The following minerals have been identified in thin sections: quartz, biotite (brown and green), sericite, muscovite, actinolite, carbonates, chlorite (one or more varieties), hornblende, rutile, titanite, epidote, apatite, tourmaline, clinozoisite or zoisite, ottrelite, staurolite, magnetite, kaolin, plagioclase, pyrite, andalusite (?), carbonaceous matter, and obscure alteration products.

Conglomerate Schist.

A large part of the Surprise formation, is made up of a type of rock which may, with almost equal propriety, be termed either metamorphic conglomerate, conglomerate schist, or more rarely conglomerate slate. The pebbles and boulders vary widely in size, with a maximum of 4 feet in diameter. They are always ill-sorted (Figure 7), and although subangular to angular fragments occur, the generally well rounded elongated forms are more conspicuous. They are of quartzite and of limestone and very rarely of granitic material. In some places limestone fragments predominate, and again those of quartzite may constitute the bulk of the fragments making up the rock in a given outcrop. Many of the limestone boulders are themselves conglomeratic and most of them have been sheared.

The red to brown or black cementing medium is wholly metamorphic and although it varies somewhat in composition from place to place, it is generally a combination of sericite, biotite, muscovite, finely interlocking grains of secondary quartz, and some calcite. Magnetite and pyrite are usually abundant.

Slate and Phyllite.

Slate and phyllite are common members of the Surprise formation, but owing to the gradations in the series, they are here treated together. In color they are dark gray or black, but on weathered outcrops have a more or less rusty appearance. The texture is fine and compact throughout, and the bedding is commonly marked by a fine delicate banding. These rocks generally exhibit a slaty cleavage that is distinct but nearly everywhere less pronounced than the shaly parting, which plays the dominant part in the disintegration of the rocks. Microscopically, the slate and phyllite are made up of irregular and generally elongated grains of quartz embedded in a fine-textured matrix of sericite and other indeterminable impure micaceous materials mingled with minute opaque particles, commonly magnetite and pyrite. The schistose structure is well shown by the arrangement of the elongated and ragged shreds of sericite in a common direction inclined to the planes of stratification. Recrystallization has resulted in the obliteration of primary features.

FIG. 8. View looking north across Surprise Canyon, Panamint mining district. a, Marvel dolomitic limestone; b, Surprise formation; c, Little Chief Porphyry (granite porphyry), here forming the crest of the range. The white band in the background is Sentinel dolomite, a conspicuous marker.

Ottrelite Schist.

In a few specimens a little ottrelite was found, and at several localities this mineral occurs in such quantity that the rock must be called an ottrelite schist. In color the rock is olive-green, with a silvery satiny luster on fresh fracture, and dotted with numerous dark-green oblong plates of ottrelite. In thin section, the porphyroblasts of this mineral occur in comparatively large crystals and sheaf-like forms embedded in a schistose matrix of sericite, quartz, and biotite. Ottrelite is arranged transverse to the foliation, thus indicating that it was developed subsequently to the structure produced in the dynamic metamorphism of the rock. Frequently the mosaic of quartz grains of the matrix, penetrates or cuts across ottrelite crystals, while the sericite of the matrix was absorbed by the ottrelite during its crystallization.

Metamorphosed Sandstones and Grits.

The arenaceous rocks which predominate in the Surprise formation are not uniform in their megascopic appearance from place to place, but are generally fine-textured, rather massive, and gray to brown or green in color. These rocks are found by microscopic study to be composed essentially of detrital grains of quartz, which show little uniformity as to either size or shape, completely cemented by confused aggregates of numerous metamorphic minerals. In some sections the clastic quartz grains are rounded, in others they are subangular to angular, and in still others round and angular grains are equally represented. There is usually no definite arrangement of grains, and the sizes vary widely in even a single section. The complex metamorphic filling is generally a combination of sericite, muscovite, biotite, calcite, and secondary quartz, with actinolite, clinozoisite, tourmaline, plagioclase, magnetite, titanite, and rutile occurring in various proportions.

Other Rocks.

Other parts of the formation are characterized by dark-green knotted schists, some with spots of biotite, and others with numerous dark elliptical areas of complex mineral aggregates. In another type actinolite is abundant, although this mineral is very seldom detected by the unaided eye. Fine-textured gray to brown quartz-sericite schists and quartz-biotite-tourmaline schists are not uncommon in the Surprise formation. Rarely thin beds of brown siliceous limestone occur, and locally the formation is cut by narrow dikes of granite, pegmatite, and hornblende diorite porphyry.

Origin and Structural Features.

The Surprise formation is a rather monotonous assemblage of fine-textured schists and slaty rocks in which it is difficult to single out any distinctive members. The mineralogical composition is not constant qualitatively and quantitatively, and often is very complex, as seen in thin section under the microscope. Nearly all traces of primary sedimentary characters which the rocks may have once possessed are now largely obliterated. In some sections detrital quartz grains have been noted, in others the remains of detrital material are wholly lacking and the rocks entirely recrystallized and reorganized with crystalloblastic texture. Moreover, some are typically cataclastic and dynamic action is evinced in the peripheral shattering of the larger grains giving rise to poorly defined mortar structure and marginal reaction effects. Although the detrital quartz grains are ill-sorted and vary widely in size and shape, nevertheless the material may have been uniform in distribution originally. Though bedding is not often seen, in places the original sedimentary structures are still visible and there can be no doubt as to their original sedimentary character. It may thus be regarded as a metamorphosed series of sandstones, grits, shales, and conglomerate, intercalated with thin limestone beds.

Although in general the schistosity of the rocks strikes north and commonly dips at high angles, yet the angle between directions of

FIG. 9. The Telescope group of rocks as seen from a point in Hall Canyon. Telescope Peak at the extreme left is 3500 feet above the observer.

schistosity and bedding varies widely from place to place. Frequently, the schistosity is normal to the contact of the Surprise formation with the Marvel dolomitic limestone. The Surprise formation contains rocks of various kinds, but folding, faulting, and metamorphism have made it impracticable to recognize any regular stratigraphic sequence.

Telescope Group.

General Statement.

The names of the eight members which comprise the Telescope group of rocks, together with their thicknesses and the order of their succession, are graphically summarized in the accompanying columnar section (Figure 3). The names of these formations are derived from geographic terms used in this part of the Panamint Range. The section is well exposed naturally (Figures 8 and 9), but owing to the ruggedness of the country, only parts of the section were studied in detail. Although most of the formations, in general, are rather well-individualized units, the precise horizons for the division planes that separate them are often matters for arbitrary decision. There is a fairly wide lithologic variation from place to place and only the most distinctive features of each stratigraphic unit are presented in the following table. The rocks have nearly all been metamorphosed to some degree and in the absence of diagnostic paleontologic evidence the age of all formations is open to question. Tentative assignment to the Lower Paleozoic has been made largely on lithologic grounds.

The Surprise formation is separated from the Telescope group of rocks by a nonconformity. Though the structure could not be determined in either the Marvel dolomitic limestone or the Surprise formation, the rocks of the Telescope group are undeformed and have an easterly dip of from 10° to 30°. Some of the rocks are now entirely recrystallized, nevertheless the change has not greatly obscured their original structure, lamination, and relations. The strike and dip of the schistose cleavage always coincides with the bedding planes.

Table of the Telescope Group of Rocks	*Thickness in feet*
8. Hanaupah formation.	
Predominantly fine-textured slaty or flaggy rocks, generally with an irregular lumpy fracture. Quartz-biotite schist with irregular streaks of sericite, finely banded with gray, green, or chocolate-brown, thin, lenticular, and generally corrugated stripes; regularly banded, micaceous schist with megascopic tourmaline and magnetite, and characterized by small oval dark-green spots; flaggy rock in which epidotized stripes alternate with finer ones of light-colored arenaceous and calcareous material; and a few beds of white to pink quartzite.----	1500±
7. Redlands dolomitic limestone.	
White, crystalline, cherty dolomitic limestone in which bedding is not readily recognized. Probably occurs as a lenticular body.--------------------------------	600±
6. Radcliff formation.	
Chiefly flaggy, corrugated, impure, arenaceous limestone, gray where fresh, reddish-brown where weathered, intercalated with a dark-gray thinly banded lime-silicate rock containing muscovite, biotite, diopside, epidote, zoisite, vesuvianite, and abundant pyrrhotite; also gray and white sandstones; gray and white mottled crystalline limestones; and finely striped gray and green slate and phyllite. --	600±
5. Sentinel dolomite.	
White, slightly arenaceous bed of dolomite, characterized by irregular patches or segregations of coarsely crystalline carbonates or more rarely chert.------------	100

	Thickness in feet
4. Wildrose formation.	
Largely conglomerate quartzite with widely scattered elongated pebbles up to 4 inches in diameter of quartzite, granite, and granite gneiss in a dark-gray to black matrix of round to angular quartz grains, completely cemented by complex metamorphic aggregates; also finely banded, brown to gray biotite schist and some crystalline limestone	500±
3. Mountain Girl conglomerate-quartzite.	
Apparently a persistent formation consisting of 10–25 feet of reddish-brown conglomerate with well-rounded pebbles up to 14 inches in diameter of quartzite and rarely of limestone, grading into a rather massive rock containing allothigenous quartz grains in a cementing medium of sericite, chlorite, muscovite, biotite, and ferruginous material	65–100
(Disconformity?)	
2. Middle Park formation.	
Fine-textured dark-gray quartz-biotite schist, spotted schist, green ottrelite schist, and dark-gray impure metamorphosed quartzitic rocks	300±
1. Sour Dough limestone.	
Crystalline micaceous arenaceous gray limestone, with alternating white and gray stripes that in some places are corrugated. (The oldest formation of the Telescope group.)	50–60
Total	3,700+

Death Valley Formation.

Distribution and General Features.

The name, Death Valley formation, is given to a considerable number of interbedded limestones, argillites, and schists which occupy the east flank of the range. Little time could be devoted to this large area and the present descriptions are necessarily sketchy. If there is any ascertainable stratigraphic sequence, it is still unknown. The interbedding of rocks which do not vary greatly in lithologic details would probably seriously hamper an attempt to separate the Death Valley formation into mapable units. Moreover, the rocks are apparently nonfossiliferous. Lithologically, they are not greatly unlike those of the Telescope group, and are in marked contrast to the more highly metamorphosed gneisses and schists of the Panamint metamorphic complex. In general, these rocks are questionably referred to the Lower Paleozoic.

Though there are local westerly dips, the beds as a whole have a general easterly dip of from 5° to 45°.

Calcareous Rocks.

The great bulk of the formation consists of generally thin-bedded calcareous rocks which may either be called impure siliceous limestones or calcareous argillites. Some rather pure crystalline limestones also occur and rather heavy-bedded varieties are not uncommon. The colors represented are white, gray, brown, and intermediate hues. Though some limestones are striped with fine bands, generally brown in color; others are spotted with small flakes of muscovite or blotched by ferritic material. One limestone is characterized by irregular patches or segregations of coarsely crystalline carbonates, another by siliceous laminations which parallel the bedding. Though the bedding and banding are generally regular, they are corrugated in many places.

Argillaceous and Arenaceous Rocks.

In general, the limestones are intercalated with rocks which may variously be called argillites, slates or shales. They are generally thin-bedded or striped slaty rocks, gray to brown or green in color, and either with or without distinct slaty cleavage or shaly fracture. The banding may be either regular or corrugated. Ordinarily no minerals are visible to the naked eye but in certain types biotite, sericite, muscovite, magnetite, pyrite, and quartz can be identified.

One distinctive rock is characterized by narrow, lenticular, and generally corrugated light-colored stripes, which alternate with wider layers of dark-green or chocolate-brown color. In places such stripes give a moire effect to a weathered surface of a flag.

Other typical members of the series include obscurely banded sericitic phyllites or schists of brownish-gray color and impure brownish weathered quartzite. Locally the formation is cut by diabase dikes and sills.

Post-Paleozoic Igneous Rocks.

Little Chief Porphyry (granite porphyry).

The stock of granite porphyry which forms the crest of the range near the head of Surprise Canyon (Figure 8) is intrusive into the Telescope group and may possibly be bounded in part by faults. It is a massive, medium-grained pink rock whose megascopic constituents are orthoclase, plagioclase, and quartz, speckled with small black prisms of hornblende. Under the microscope the essential minerals, named in order of apparent abundance, are orthoclase, microcline-perthite, quartz, albite-oligoclase, hornblende, and biotite. The texture is porphyritic with relatively large phenocrysts of microcline-perthite and orthoclase in a microgranitic groundmass. The pale-green, almost colorless hornblende, occurring in comparatively small idiomorphic crystals, is characterized by streaks of brown that have probably resulted from leaching. Apatite, magnetite, titanite, and muscovite are accessory minerals.

Dikes.

Hornblende diorite porphyry dikes cut the Marvel dolomitic limestone, Surprise formation, and the rocks of the Telescope group. Therefore the dikes were intruded subsequent to the folding of these

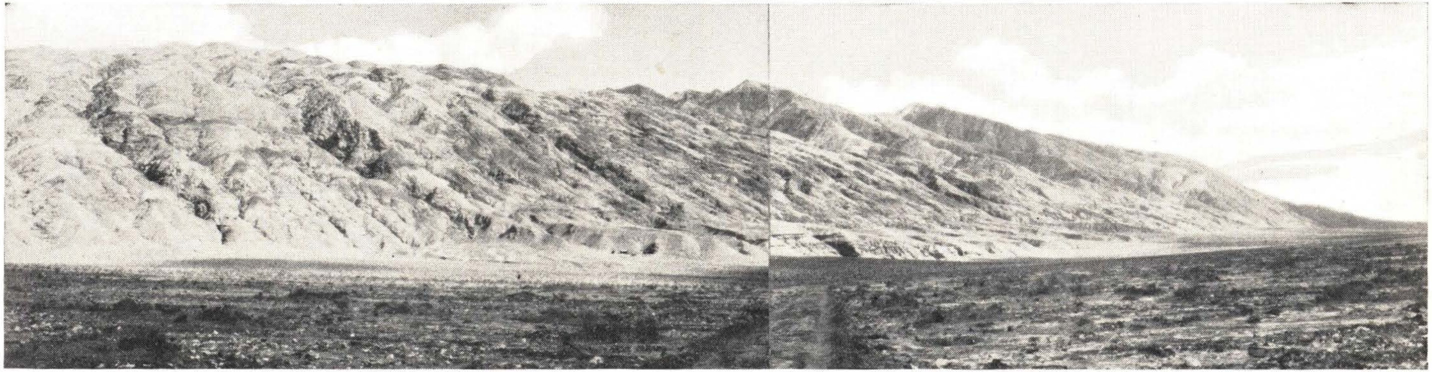

Photo by J. P. Buwalda.

FIG. 10. Panamint Valley fault scarp, showing remnants of alluvial fans deposited before the more recent faulting took place. View from a point several miles south of Ballarat.

older sedimentary formations. The dikes are rather inconspicuous, ranging in width from 2 to 15 feet with an average of about 5 feet. They have a general strike of from north-south to northwest-southeast and dip from 70° to vertical. Many of them are continuous for a distance of nearly a mile. The color of the freshly fractured rock is olive-green. Prisms of hornblende, where present, represent the only mineral visible to the naked eye. Its decomposed character prevents its being classified satisfactorily. The groundmass is holocrystalline and consists essentially of hornblende and plagioclase. The prevailing green color of the rock has resulted from the epidotization of the feldspar. Augite is present in some sections. Clinozoisite, biotite, chlorite, and interstitial quartz are secondary minerals.

FAULTING

More than one period of faulting was involved in the production of the west escarpment of the range, and the more recent movements are recorded by scarps in the fresh alluvial fans and talus patches at the base of the cliff. The rocks which form the lower part of the escarpment are everywhere tremendously sheared and brecciated. Moreover, the tilting of the Panamint block toward the east is particularly well shown in the east-slanting Lower Paleozoic rocks which form the higher parts of the range. Many interesting features in connection with this faulting have previously been recorded by Noble [11] and Davis.[12] The subject was not studied in detail by the author and only a few significant features of the complex structural history of the range will be mentioned. Its western flank is here unusually steep and rugged, and the escarpment of the range displays a remarkable development of triangular facets, so recently formed that new talus cones are just appearing along the base of the precipitous slope. In this connection it is interesting to note that, although Hall Canyon is 8 miles long, it has a very insignificant fan which is no larger than the fans of many mere gashes. Consequently, one has some difficulty in a drive along the base of the range in locating this, a major canyon of the range. Other similar examples of canyons south of Ballarat are at once brought to the attention of a passing observer (Figure 10).

Thus, while many of the large pre-faulting fans have been completely buried under post-faulting alluvium, a mile or more north or south along the escarpment these old fans have not been entirely depressed. The best example of this is in the large fan at the mouths of Tuber and Wildrose Canyons. Here recent faulting has produced a large and well-defined trench which runs across the fan near its apex (Figures 11 and 12). The feature is undoubtedly a graben, although in keeping with the structural history of the range, may have had a complex history. However, the most outstanding feature is the abrupt truncation of prefaulting fanglomerate just south of Ballarat which has given the deposit a peculiar mesa-like appearance. Its flat-topped surface rises nearly 500 feet above the valley floor. It seems proper to regard it as a remnant of the fan from Pleasant Canyon that

[11] Noble, L. F., The San Andreas Rift and Some Other Active Faults in the Desert Region of Southeastern California. Carnegie Inst. Wash. Yearbook, no. 25, pp. 425–428, 1925–1926.

[12] Davis, W. M., The Rifts of Southern California. Amer. Jour. Sci., 5th Ser., vol. 13, pp. 57–72, 1927.

has been cut off by an oblique fault which probably runs in a southwesterly direction from near the present mouth of Happy Canyon.

In the enormous thickness of fanglomerate, of such remnants of prefaulting fans as exist, dips up to 45° either west or east are not uncommon. Moreover, unconformities in fan material have been noted in several places.

The remarkably steep front frequently persists to the very base of the cliffs and in places the playa-flat, occupying the deepest part of Panamint Valley, lies directly against the escarpment. As has already been suggested, the range is not bounded by one continuous fault, and as Noble has pointed out

> "* * * rather, a succession of faults, each of which is offset from the other along the strike. Consequently their escarpments [of both the Panamint Valley and Death Valley Faults] have a roughly zig-zag pattern and are indented by great concave bights or cusps where the offsets occur. At some

FIG. 11. View looking north along fault-trench, from a point on the western escarpment about four miles south of Wildrose Canyon. The trench is nearly a mile wide and four miles long and is composed of old Quaternary alluvial deposits. It crosses the prefaulting alluvial fans of Wildrose and Tuber Canyons near their apices.

> places the bights mark cross-faults; at others they appear to represent areas of great and sudden downwarp. At many places the faults exhibit enormous changes in amount of throw in distances of a few miles." [13]

The escarpment reaches a probable maximum of 40° as measured on the nose 6 miles north of Ballarat, in the vicinity of the Indian Ranch. All the faults which bound the range, wherever the writer has seen them, are normal and dip west at angles ranging from 60° to 90°. No evidence was obtained to support the view that the approximately 35° slant of the rock-faces may approach that of the dissected fault-plane.

Faulting, with the exception of the recent border faulting on the west front of the range, is probably not an outstanding feature of the

[13] *Op. cit.*, p. 427.

structure of the area as a whole. Although minor faults of small displacement are numerous, the writer did not consider it practical to represent them on the map (Plate IV). Most of the faults are normal and have a prevailing northerly trend.

CONCLUSIONS

The essential geologic features of this part of the Panamint Range have been set forth in some detail in the body of the paper and summarized in the abstract. Although this reconnaissance study has failed to disclose anything of very unusual or striking significance, certain features have come to light which have particular interest because of their relation to broader geologic problems.

The region is characterized by extreme topographic contrasts and by many youthful physiographic features. Attention has been called to the preservation of an old erosion surface in this part of the Panamint Range, which is undoubtedly a counterpart of similar topographic forms that have been preserved in other Basin Ranges. The Panamint Range is a particularly good example of fault-block structure inasmuch as the mountain-making movements have continued into such recent times that the offsets produced in the faulting are plainly evident in the present topography. They are normal faults and dip west at angles ranging from 60° to 90°. Moreover, the north-south structures which characterize that part of the Great Basin lying north of the Garlock fault is well shown in the Panamint Range.

It has not yet been possible to correlate any of the rock formations in this part of the Panamint Range with known sections in the general region. It has been necessary, therefore, to apply local geographic names to the formations herein described. The older rocks are greatly sheared and the highly crumpled condition of certain rock masses has made it impracticable to recognize any regular stratigraphic sequence. This is due, in part at least, to the fact that several schist and limestone bodies occur in great lenses. It is impossible to retrace all of the changes through which these rocks have passed or determine each step in the probable complex history of their metamorphism. The dominant process seems to have been regional in character and very little contact metamorphic effects have been noted. In a large measure also, the folding is attributed to the forces attending regional metamorphism. In general the aplitic rocks show little deformation. The older rocks on the west slope commonly show a westward dip of the foliation, whereas the younger formations, forming the crest of the range and the Death Valley side, in general dip gently eastward. Although diligent search has been made, no definitely determinable fossils have been found and consequently the tentative assignment to the Lower Paleozoic is based wholly on lithologic considerations.

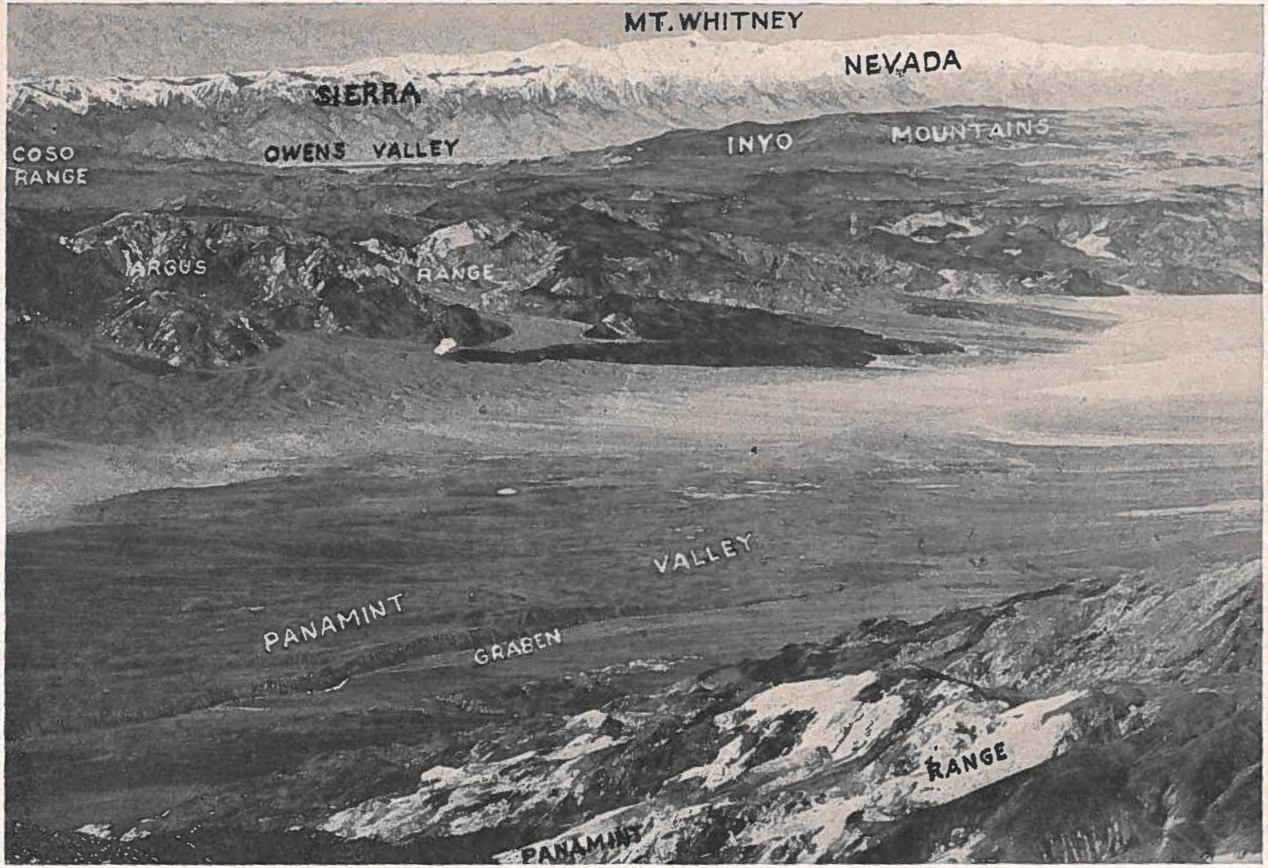

FIG. 12. Northwesterly view from the summit of Telescope Peak, showing the well-defined trench or graben, gashed across a great fan ot the mouth of Wildrose Canyon. In the distance, across Panamint Valley, is the Argus Range. To the right and beyond are the Inyo Mountains and the snow-capped Sierra Nevada.

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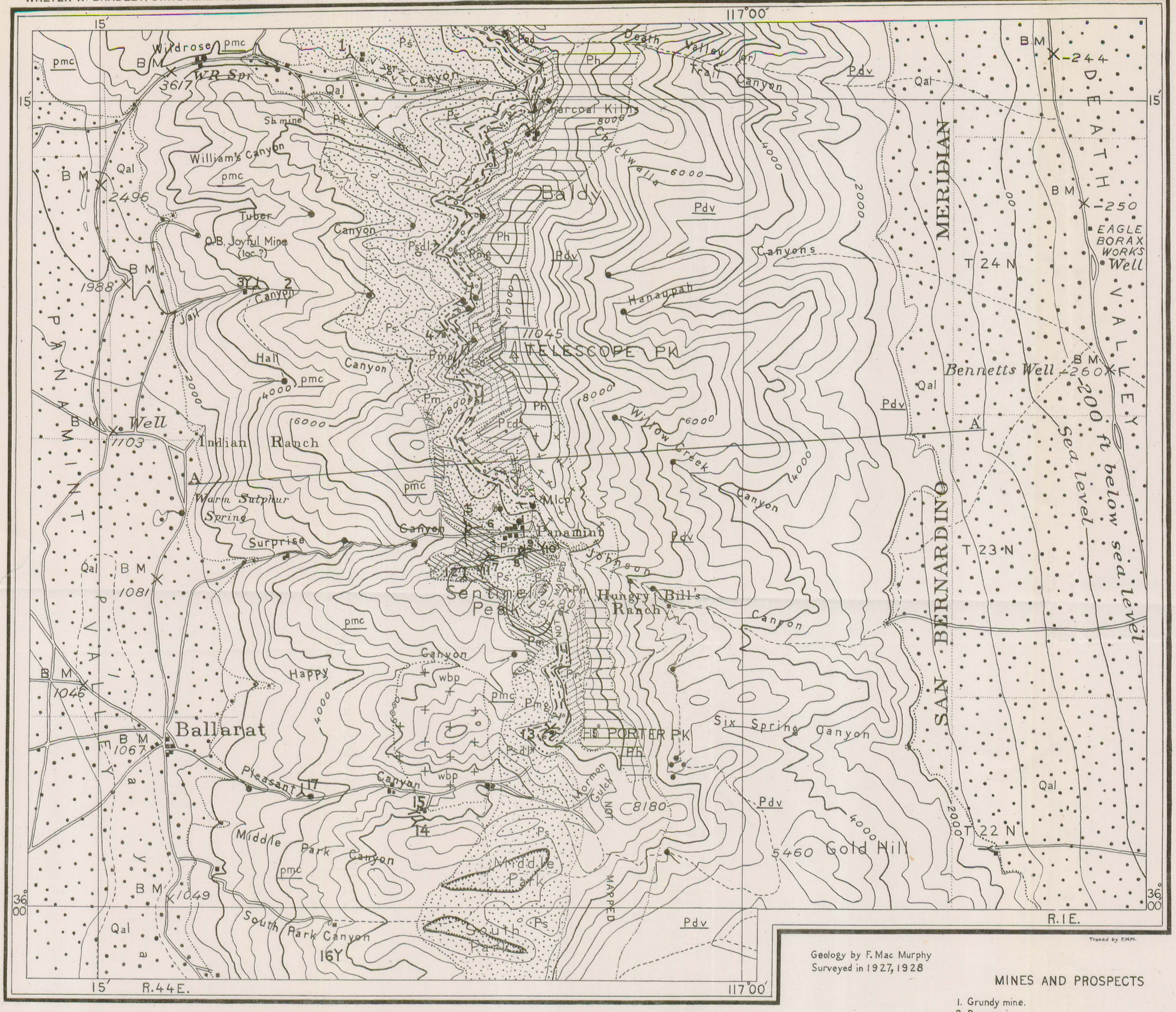
CALIFORNIA STATE DIVISION OF MINES
WALTER W. BRADLEY, STATE MINERALOGIST

PLATE IV

GEOLOGIC BRANCH
OLAF P. JENKINS, CHIEF GEOLOGIST



Geology by F. Mac Murphy
Surveyed in 1927, 1928

LEGEND

SEDIMENTARY AND METAMORPHIC ROCKS

QUATERNARY
- Qal — Alluvium
- Pdv — Death Valley formation

LOWER PALEOZOIC (?) — Telescope group
- Ph — Hanaupah formation
- Prd — Redlands dolomitic limestone
- Pr — Radcliff formation
- Psd — Sentinel dolomite
- Pw — Wildrose formation
- Pmg — Mountain Girl conglomerate-quartzite

DISCONFORMITY (?)

- Pmp — Middle Park formation
- Psdl — Sour Dough limestone

NONCONFORMITY

- Ps — Surprise formation
- Pm — Marvel dolomitic limestone

PROBABLE UNCONFORMITY

PRE-CAMBRIAN AND LOWER PALEOZOIC (?)
- pmc — Panamint metamorphic complex

IGNEOUS ROCKS

PRE-CAMBRIAN (?)
- wbp — World Beater porphyry (porphyritic granite)

MESOZOIC (?)
- Mlcp — Little Chief porphyry (granite porphyry)
- gr — granite

Approximate location of the Panamint District as mapped

Actual and inferred boundaries

Trail

Tunnel

Springs

MINES AND PROSPECTS

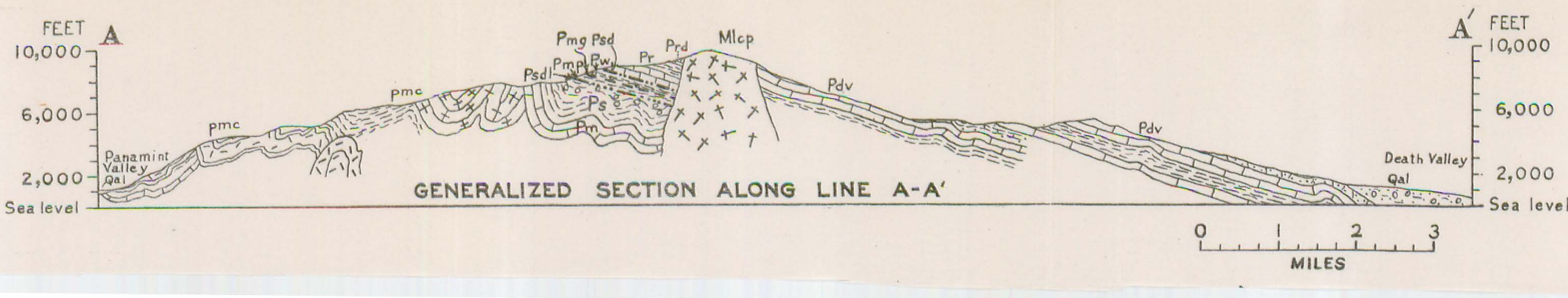
1. Grundy mine.
2. Burro mine..
3. New Discovery (Gem group).
4. Horn Spoon mine.
5. Camp Bird mine.
6. Stewart's Wonder workings.
7. Wyoming workings.
8. Kenneth prospect.
9. Revenue prospect.
10. Bachelor workings.
11. Hemlock mine.
12. Alabama and Hudson River prospects.
13. Mt. Girl and Mt. Girl Ext. properties.
14. Radcliff mine.
15. World Beater mine.
16. Big Horn mine (formerly Gibraltar).
17. Anthony mine.

Base enlarged from U.S. Geol. Survey Maps of the Ballarat, Furnace Creek and Searles Lake quadrangles
Culture revised and minor topographic changes made in 1928 by F. Mac Murphy

Scale
2 1 0 2 4 Miles
2 1 0 2 4 Kilometers
Contour interval 500 feet.
Datum is mean sea level

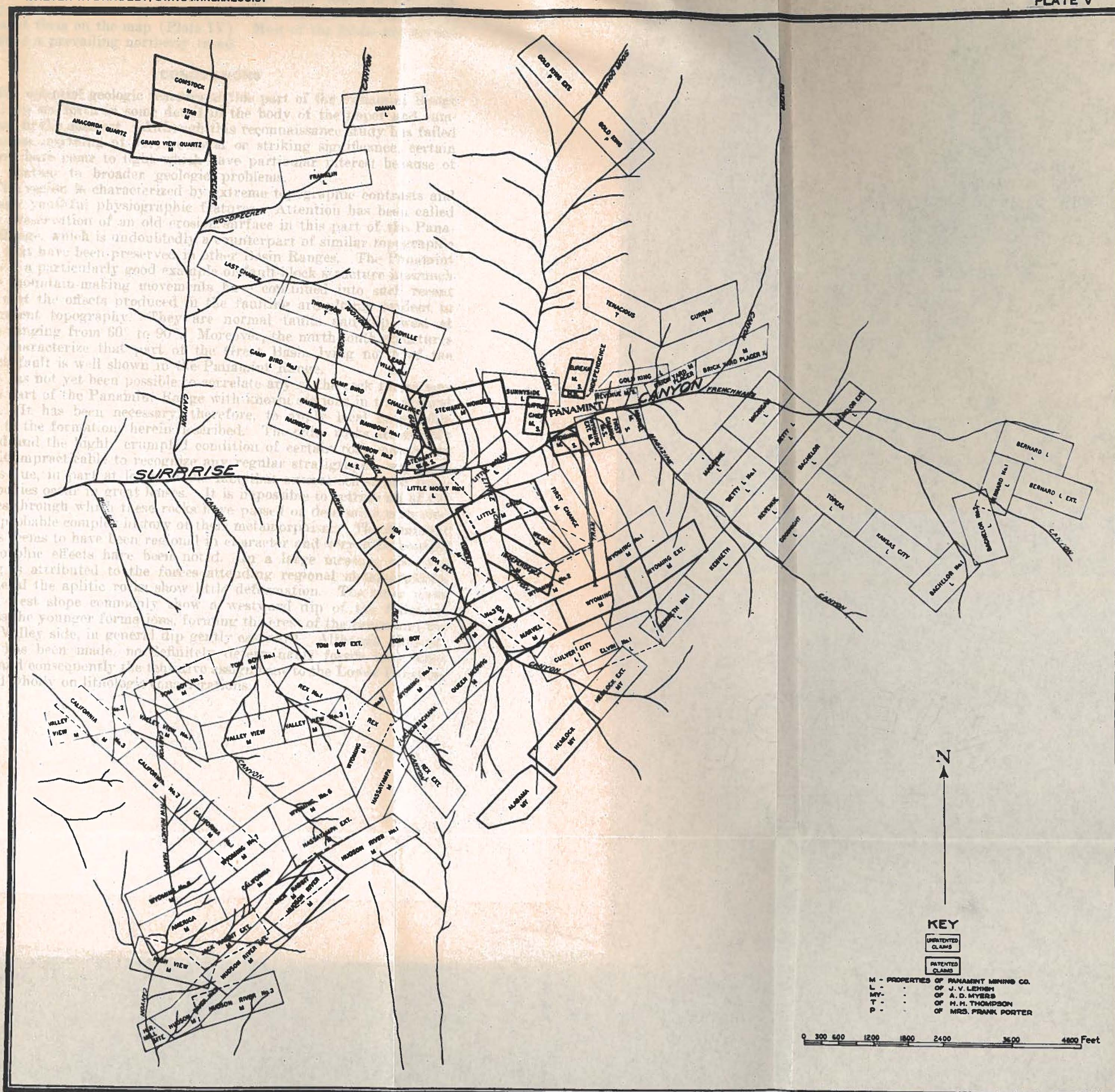
TRUE NORTH
MAGNETIC NORTH
16½°
APPROXIMATE MEAN DECLINATION 1911.

RECONNAISSANCE GEOLOGIC MAP OF A PART OF THE PANAMINT RANGE, CALIFORNIA



GENERALIZED SECTION ALONG LINE A-A'

Note: Elevation of U.S. Coast and Geodetic Survey's triangulation station on Sentinel Peak established in 1926 is 9627 feet above mean sea level.



CLAIM MAP OF THE PANAMINT DISTRICT, INYO COUNTY, CALIF.

Compiled and revised by F. MacMurphy from various old maps of the district. Positions of claims are largely approximate 1927